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Mineral Trioxide Aggregate (MTA): Physical Properties and Clinical Uses

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Introduction

Post-treatment endodontic disease is mainly due to leakage of irritants into the apical tissues produced from microbes within the root canal system (1). An endodontic root repair material should prevent leakage by providing an acceptable seal. Mineral trioxide aggregate (MTA) was developed in 1993, approved by the Federal Drug Administration in 1998, and became commercially available as ProRoot® MTA (2). A gray version (GMTA) was first produced, however was found to produce discoloration in esthetic zones, therefore a white version (WMTA) was introduced in 2002.

Chemical Properties

MTA powder contains fine hydrophilic particles that set, in the presence of moisture from a porous compact colloidal gel, into a solid cement. Electron probe microanalysis showed that the principal components, 73% of the GMTA and 82% of WMTA, are calcium, silica and bismuth oxides (3). Bismuth oxide is added to impart radiopacity to the cement which is necessary to help the clinician differentiate MTA from dentin and adjacent anatomical structures (4).

Setting Time

MTA's long setting time is one of the drawbacks of the material. On average, an initial setting time for both MTA products has been shown to be 55 minutes, whereas the final setting time for both are between 2.5-3 hours (5, 6). Generally, endodontic as well as restorative treatment cannot be completed until after the final setting time for orthograde placement of MTA, resulting in the need for a second appointment.

Setting Expansion

MTA mixed according to the manufacturer's instructions (1 gram powder with 0.33 grams water) undergoes setting expansion, which facilitates sealing of the canal (7). However, in a clinical setting, MTA is typically mixed by estimating the powder to water ratio. A recent study found that varying the powder to water ratio had no effect on setting expansion, however it is unknown whether other physical properties are affected (8).

Solubility

MTA will likely be in contact with the periodontium, so the lack of solubility would be an ideal characteristic for an endodontic repair material. Benchtop investigations have reported minimal or no solubility for MTA when placed in distilled water (5, 6, 9). MTA is mainly composed of an insoluble silica matrix; hence there should not be a concern for complete solubilization (9).

pH

The pH of MTA may reach as high as 12.5 (5). This high pH is attributed to the formation of calcium hydroxide as a by-product of its setting reaction (9). This could aid in inhibition of microbial growth and/or resorption when used as an apical barrier and/or obturation material.

Compressive Strength

Root end filling materials do not bear direct pressure as do most restorative materials, but in certain applications, such as furca perforation repairs, MTA will be subject to occlusal loading. The compressive strength three weeks after the set of MTA, compared to IRM or Super EBA, is not significantly different (5). MTA's compressive strength is not significantly affected by condensation pressure; however using a lower pressure facilitates favorable crystalline cement formation (10). It is recommended to place a wet cotton pellet over MTA to facilitate the setting reaction. Two-sided moisture, periapical tissue moisture, in combination with a moistened intracanal pellet, results in increased flexural strength after 24 hours (11).

Clinical Uses

An ideal endodontic root repair material should be biocompatible, insoluble in tissue fluids, and dimensionally stable (12). MTA has demonstrated superiority in sealing ability and biocompatibility when compared to those of amalgam, IRM and Super EBA (13, 14). MTA was developed initially as a <u>root-end filling</u> material and subsequently has been utilized for multiple clinical applications.

- MTA has demonstrated a high success rate for <u>repair of root perforations</u> (15, 16).
- As a <u>direct pulp capping material</u>, MTA was shown to have a favorable outcome in 97.9% of cariously-exposed teeth (17).
- MTA used in <u>pulpotomy</u> procedures, in teeth with incomplete root formation, demonstrated healing in 94.7% of cases (18).
- MTA has been utilized for <u>partial and complete obturation</u> during non-surgical root canal treatment (19).

- Roots with open apices obturated with MTA in one visit were healed (92.3%) with a minimum of a one year recall (20).
- MTA was used as an apical plug to manage traumatic injuries (horizontal fractures to maxillary incisors). MTA was placed to obturate the coronal segment and radiographic healing was evident at the 2 year follow-up (21).

Conclusion

MTA can be a challenging material to use considering its difficult handling properties, slow setting time and difficulty in removal due to an unknown solvent. The patent on ProRoot® MTA has expired recently and researchers are striving to develop an enhanced version. Recently, EndoSequence® Root Repair Material and DiaRoot® Bioaggregate have been released in the U.S. with little research completed, yet both have similar properties to MTA. Numerous studies within the last three years have also used additives to shorten working time and modify handling properties, but evidence is still lacking to support these materials as improvements. Overall, MTA's bioactive properties (release of calcium and hydroxyl ions), biocompatibility (nonirritating to periapical tissues) and sealing ability provide a suitable mechanism for bacterial entombment, neutralization and inhibition within the canal system. MTA has the ability to create an ideal environment for healing and recent outcome studies have shown promising results, therefore MTA remains to be the material of choice for a number of clinical applications.

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